# The Neural Network for Vertical Handover Procedure


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***Abstract*—The paper suggests to apply a neural network in cellular networks in order to improve the vertical handover process. The proposed neural network is a multilayer perceptron. The paper presents the proposed architecture of the neural network. The operation of the perceptron has been described. Simulation of the neural network operation in Matlab software was performed.**



***Keywords—neural network; handover; mobile***


## I. Introduction

Over the past few years, telecommunication technologies are being fast developed [1], [2]. The huge efforts are applied towards research, development and deployment of heterogeneous networks. Existing diversity of mobile technologies allow subscribers to be connected to any network and to benefit from variety of services.

While heterogeneous networks incorporate various mobile technologies, the major challenge is providing the seamless mobility and high quality of service. An important factor in providing the seamless mobility in heterogeneous networks is a handover procedure [3]–[5].

Vertical handover is the mechanism of transferring a terminal from one network to another. Handover procedure determines the best target network and decides whether to perform the handover operation or not.

The handover process has three steps: handover initiation, handover decision, handover execution. In the first step, the UE discovers all available networks. In the second step, the UE evaluates the available networks and makes a decision according some criteria. The third step is establishing connection to a target network. UEs tends to connect the best target network, therefore, network selection can be regarded to be a decision-making problem. Therefore, the handover problem is solved by searching an optimal solution.

One of the challenging problems in handover process is the selection of an optimal network that maximizes the subscribers satisfaction. Moreover, sometimes the UE moves very quickly, so the algorithms of handover decision must also be fast and able to yield a solution in real time.

Various heterogeneous networks differ by their features and parameters. So, there is a relevant scientific task of creating an effective handover decision mechanism adapting dynamically in the changing wireless environment.

The ubiquitous decision-making schemes based on one criterion, such as received signal strength indication, are used for horizontal handover and are not very effective due to heterogeneity of parameters and characteristics of a wireless communication network.

Existing decision-making algorithms for handover process can be divided into two classes according to the method of processing input parameters: mathematical and intellectual. The intellectual algorithms process more input criteria than mathematical ones.

Artificial intelligence (AI) techniques, such as fuzzy controllers, neural networks, and genetic algorithms [6]–[8] are employed widely in communication networks [9] to solve various tasks.

Application of AI techniques in cellular network would give more capability in traffic handling. Moreover, AI techniques are employed to support decision-making processes. Therefore, AI-based heterogeneous networks can satisfy expected needs and face new challenges [10]. Solutions for AI schemes for handover decision are outlined in [11]–[16].

Intelligent methods of parameter processing are based on fuzzy controllers, neural networks, genetic algorithms and chaotic systems [17, 18]. A handover algorithm based on a fuzzy controller allows processing results of inaccurate measurements and well suits for wireless communication [19]. A handover algorithm based on neural network allows choosing the best available wireless network considering the subscriber's settings, device capabilities and network functions [20]. A handover algorithm based on genetic algorithms allows estimating probabilities of successful transmission in heterogeneous networks, which leads to an increase in network performance [21].

Thus, efficiency and quality of wireless communication can be increased by using intelligent algorithms in the



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vertical handover procedure. Since artificial neural networks are able to process large amounts of data more quickly in comparison to fuzzy controllers [22, 23] and genetic algorithms [24], we proposed to develop a neural network for application in intelligent decision-making algorithm of vertical handover.

The authors have already proposed the handover neuro-fuzzy controllers for cellular networks in [25, 26]. This study provides results of further investigations.

Therefore, the objective of this paper is a neural network for vertical handover mechanism in heterogeneous networks.

Thus, the aim of this study is to develop a neural network for using in the vertical handover mechanism.

Thus, the following tasks should be solved:

- determination of criteria for the handover procedure decision;

- development of a device for the handover decision procedure;

- simulation of the proposed device operation.

## II. NEURAL NETWORK

The development of the neural network-based decision-making system for handover operations consists of the following stages:

- the architecture of a neural network and the algorithm of its training is substantiated;

- neural network training is performed;

- the trained neural network is tested.

In the vertical handover decision, the criteria are playing a crucial role in taking a correct decision about switching to another network and in achieving uninterrupted mobility scenarios.

We propose to apply the following four parameters of a wireless network with the specified ranges as input values of the neural network:

received signal strength indication (-90… -40 dBm);

distance between a mobile station and a base station or access point (0… 100 m);

bit error rate (0…1e$^{-1}$);

bandwidth (0…12000 Kbps).

In addition, one can use additional parameters such as subscriber's speed, security, cost, power consumption.

Being universal approximators, multilayer perceptrons and radial-base networks are usually utilized to solve such kind of problem as decision-making.

The proposed neural network (Fig. 1) is a multilayer perceptron. The input layer consists of three neurons $x_i$. The hidden layer consists of nine neurons $y_j$. The output layer consists of one neuron z. The Input and hidden neurons are connected by synapses with weights $w_{ij}$, the hidden and output neurons are connected by synapses with weights $v_{jn}$. The neuron inputs are the received signal strength indication from the target base station R, the distance to the target base station D, the bit error level B, and the bandwidth W. The output is the handover decision.

Each input neuron $x_i$ transmits the obtained value, multiplied by the corresponding weight, to all neurons of the hidden layer.

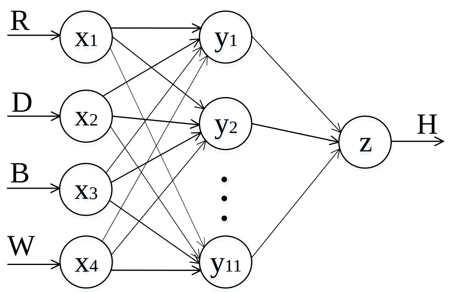


Fig. 1. Neural network.

The proposed artificial neural network functions as follows. Four input values enter four input layer neurons $x_i$, where they are multiplied by the corresponding weights. The obtained values $x_i w_{ij}$ are transmitted to all neurons of the hidden layer, where they are added with a bias. The hidden layer neuron yields the total value $y_{jS}$

$$y_{jS}=x_1 w_{1j}+\ldots+x_4 w_{4j}+w_{0j},$$

where $w_{0j}$ is the bias of hidden layer neurons.

The activation function value is calculated for each neuron of the hidden layer

$$y_j=f(y_{jS}).$$

For this case, the activation function is the hyperbolic tangent function.

The obtained values are added in the output layer neuron z and the total output $z_s$ is calculated

$$z_s=y_1 v_1+\ldots+y_{11} v_{11}+v_0,$$

where $v_0$ is the bias of the output layer neuron.

The activation function value is calculated for the output layer neuron as

$$z=f(z_S).$$

The output layer neuron calculates the error as

$$\delta=(t-z)f'(z_S)$$

where t is the target value.

Also, the output layer neuron calculates the weight adjustment:

$$\Delta v_j=h\times\delta\times y_j,$$

and the bias adjustment:

$$\Delta v_0=h\times\delta,$$

where h is the learning factor.

The hidden layer neurons calculate the total error of the output neuron, which enters the j-hidden neuron,

$$\delta_{jS}=\delta\times v_j,$$

the error

$$\delta_j=\delta_{jt}\times f'(y_{jS}),$$

the weight adjustment

$$\Delta w_{ij}=h\times\delta_j\times x_i,$$

and the bias adjustment

$$\Delta w_{0j}=h\times\delta_j.$$

The weights are updated:

$$w_{ij}=w_{ij}+\Delta w_{ij},$$

$$v_{ij}=v_{ij}+\Delta v_{ij}.$$

The neural network is being trained until the total standard error is minimized.

## III. Simulation

The operation of the developed neural network was simulated in Matlab software. Matlab provides command-line functions and apps for creating, training, and simulating artificial neural networks. After creating the network, it is possible to generate Matlab code to automate tasks.

Fig. 2 shows the training process in the neural network according to given input data. Fig. 3 shows that the training error was minimized, so the training was successful. Fig. 4 shows a regression graph, which confirms good correlation between input and target values.

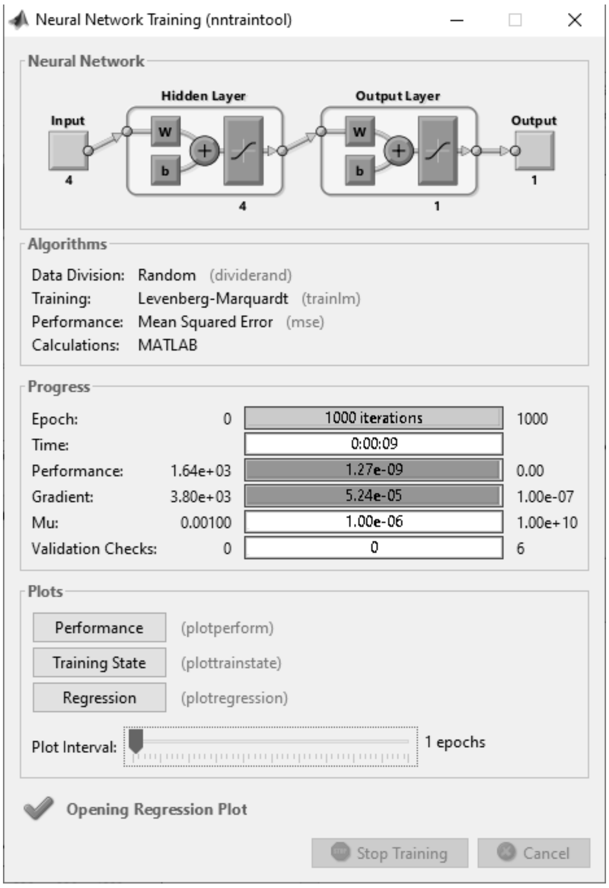


Fig. 2. Network training.

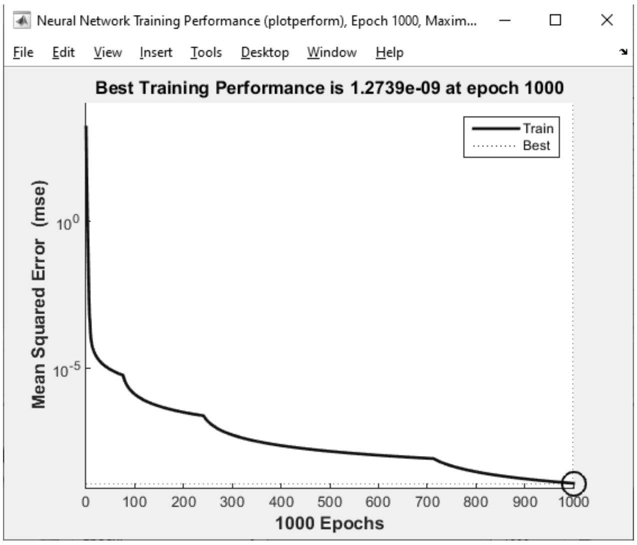


Fig. 3. Training error.

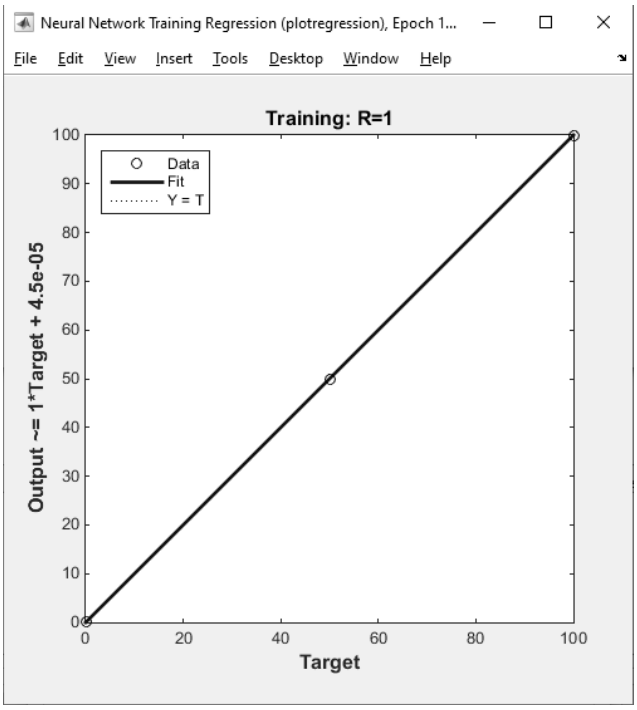


Fig. 4. Regression.

The further study will be devoted to more deep and comprehensive mathematical modelling as well as to testing of the neural network and will consider more input criteria.

## IV. Conclusion

Relevant handover algorithms provide eligible features of the wireless communication. Nevertheless, some additional factors such as topographical characteristics, traffic parameters, and propagation environment complicate operation of the handover algorithms. Moreover, in cellular networks, the handover decision procedure may be quite complicated due to several criteria to be considered.

That is why, research of algorithms for heterogeneous wireless networks is a challenging area. The main difficulty is to develop a technique that will be useful in a wide range of conditions and will consider a large amount of parameters.

This paper has proposed a vertical handover decision based on a neural network for cellular networks. The neural networks yields a decision whether a target base station is suitable for the vertical handover operation.

In this paper, the neural network with four input parameters has been developed in order to improve the handover decision operation. The proposed neural network was simulated in Matlab software and trained successfully.

The proposed neural network can be utilized in the vertical handover mechanism of heterogeneous cellular networks. Application of the neural network in the handover system improves its ability to select the best target network among available ones and reduces a number of unnecessary handovers.

Moreover, consideration of other parameters of heterogeneous networks can enhance the suggested handover neural network. Besides, handover mechanism can be optimized by combining neural network techniques with fuzzy logic and genetic algorithm methods that provides computation considering the features of cellular networks and smart devices.

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